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Natural woodland composition and vegetation dynamic during the Linearbandkeramik in north-western Europe (central Belgium, 5200–5000 b.c.)

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ABSTRACT

Charcoal analysis was carried out on seven Linearbandkeramik sites in Hesbaye (central Belgium), where a first and a second stage of settlement were highlighted. This provides opportunity to examine the vegetation dynamic during the LBK culture which lasted around 200 years in this region. The natural forest at the arrival of the Neolithic farming communities may have been quite closed, with low species diversity. A few gaps in the forest canopy probably allowed the local development of heliophilous species like Rosaceae as well as shrubs in the undergrowth. The impact of human activities, like house building, setting up fields or foddering, favoured the availability of light and the development of heliophilous post-pioneer taxa like Maloideae which have been particularly exploited for firewood during the second stage of settlement.

1. Introduction

The degree of openness and density of forest stands, as well as access to water and the availability of raw materials, probably played a role in influencing the locations of the LBK settlements. Based mainly on pollen evidence and ecological data, the closed or open nature of the woodland canopy has already been discussed by several authors (Svenning, 2002; Mitchell, 2005; Kreuz, 2008). It is likely that the forest was quite closed at the time, with forest openings being created by various ecological factors, such as natural fire and breaking down of old trees, and being maintained by the grazing of large herbivores (Vera, 2002; Kreuz, 2008). Furthermore, Mesolithic hunter–gatherers may have had at least a local influence on the Atlantic forest, using fire to create open areas which would have been more favourable to fruiting trees or to game animals, especially near water sources (Simmons and Innes, 1987; Innes and Blackford, 2003).

Charcoal evidence has only rarely been used to consider questions of forest composition and vegetation dynamic during the LBK. Indeed, "data for Bandkeramik periods is not evenly distributed at present, it is not possible to say anything about changes in the firewood obtained over time" (Kreuz, 2008: 58). Synthetic research has predominantly been carried out to the east of the Rhine, such as in the Merzbach valley (Castelletti and Stäuble, 1997), or in Hessen (Kreuz, 1990, 2008), both located in western Germany. Very few analyses are known within the last colonization front, in the second cultural phase of LBK extension, which corresponds to the Rhine crossing around 5300 b.c.

In central Belgium, the presence of Neolithic groups is attested from the LBK Ib on the basis of ceramic typology, but occupation becomes more established during the middle and recent LBK, between 5200 and 5000 b.c. (Jadin, 2003; Bosquet et al., 2004). In Hesbaye, the ceramic typo-chronology suggests two successive stages of settlement (Bosquet et al., 2008). Ceramic sherds coming from house longitudinal pits of the first stage date from phase IIc whereas structures attributed to the second stage of settlement date from phase IId (Modderman, 1970; Bosquet et al., 2008). Lithic and ceramic raw materials are also distinct between the first and the second stage of settlement (Beugnier, 2005; Martin, 2007; Bosquet et al., 2008; Golitko, 2010). Despite the plateau effect on calibration curve, AMS radiocarbon dating (Fig. 1) seems to support the succession of the two stages (Bosquet and Golitko, 2012). Moreover, the earliest houses are most often at some

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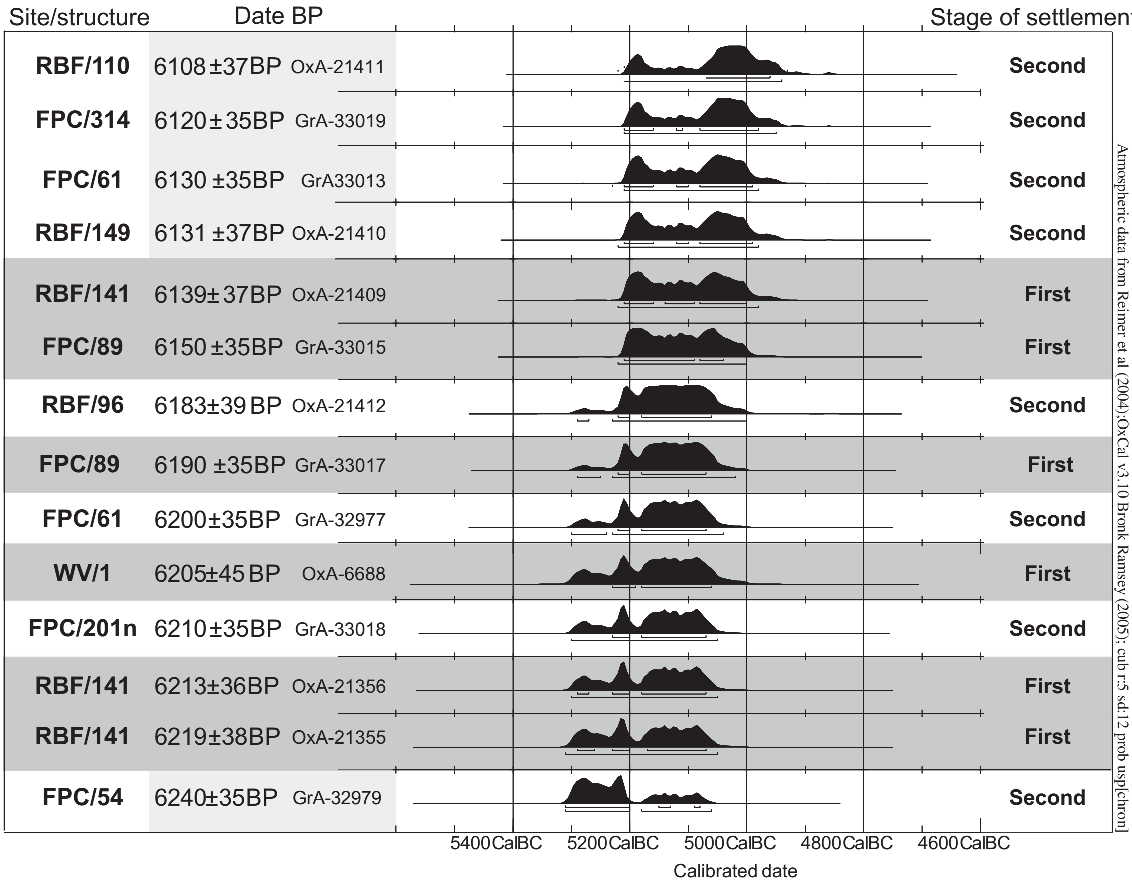

Fig. 1. AMS radiocarbon dating of LBK occupations discovered thanks to the rescue excavations led by the SPW with the collaboration of RBINS, at the end of the 1990s, in Hesbaye. The dating have been realized on cultivated cereals and hazelnut shells (from Bosquet and Golitko, 2012). In grey, structures attributed to the first stage of settlement.

distance from the structures of the second stage or even outside surrounding ditches when there is one (Bosquet et al., 2008). This spatial distribution gives the outstanding opportunity to discuss forest exploitation through the LBK, as well as providing an overview of the wood species that composed the original "natural" forest that existed before any significant human influence in central Belgium.

2. Environmental and archaeological contexts

2.1. Hesbaye liégeoise

The region is located in the east part of central Belgium. It is a plateau region demarcated roughly by the river Geer to the north, the Meuse to the south and the Méhaigne to the west (Fig. 2). The oceanic and temperate climate is characterized by relatively cool and wet summers. Average temperatures range from 3.1 °C in January to 17.7 °C in July. The average rainfall is 804.8 mm per year (source: Royal Meteorological Institute of Belgium). Today, the thick loess cover is favourable to the practice of extensive agriculture mainly of sugar beet and cereals. In Hesbaye, the rare wooded places are dominated by pedonculate oak (*Quercus robur*) and ash (*Fraxinus excelsior*) which form 70–90% of the forest. Hazelnut (*Corylus avellana*) and elder (*Sambucus nigra*) dominate the shrub canopy (Noirfalise, 1984). The alluvial forest is composed of four main species: alder (*Alnus glutinosa*), ash, elm (*Ulmus campestre*) and bird cherry (*Prunus padus*) (Noirfalise, 1984). The riparian flora is also represented by willow stands (among others *Salix purpurea*, *Salix fragilis*, *Salix trianda*, etc.) and alder (*Alnus*) species (Noirfalise, 1984).

2.2. Sites

Seven sites are analysed (Fig. 2). Waremme–*Longchamps* has been excavated several times between the 1980s and 2005 by the Royal Belgian Institute of Natural Sciences (RBINS) and the University of Illinois at Chicago (Cahen et al., 1990; Keeley et al., 2005). Alleur has been the subject of several excavation campaigns carried out by the Direction de l'Archéologie du Service public de Wallonie (SPW) between 1998 and 2007 (Marchal, 1998, 1999; Otte and Delye, 2000; Delye et al., 2002). On this site, the archaeobotanical samples come from the 2000 and 2007 field seasons. Finally, Remicourt–*Bia Flo* II, Fexhe-le-Haut-Clocher–*Voroux Goreux*, Remicourt–*Fond de Momalle*, Waremme–*Vinâve* and Fexhe-le-Haut-Clocher–*Podrî l'Cortri* and were discovered in Hesbaye thanks to the rescue excavations led by the SPW with the collaboration of RBINS, at the end of the 1990s in the frame of the extension of the TGV (high-speed train) line between Brussels and Liège (Bosquet et al., 2004). The sites include between one and twelve identified domestic units. *Longchamps*, *Bia Flo* and *Voroux–Goreux* are surrounded by an enclosure. The two stages of settlement are identified at *Bia Flo*, *Longchamps* and *Podrî l'Cortri* (Bosquet et al., 2008). Waremme–*Vinâve* delivers only indications of the first stage. At *Voroux Goreux*, preliminary analysis of the ceramics indicates the presence of the second stage only. At Alleur and *Momalle*, the distinction of the two stages is not possible for the moment because of the lack of fine ceramic periodization and radiocarbon dating. However, most part of the sites seem to belong the second stage of settlement.

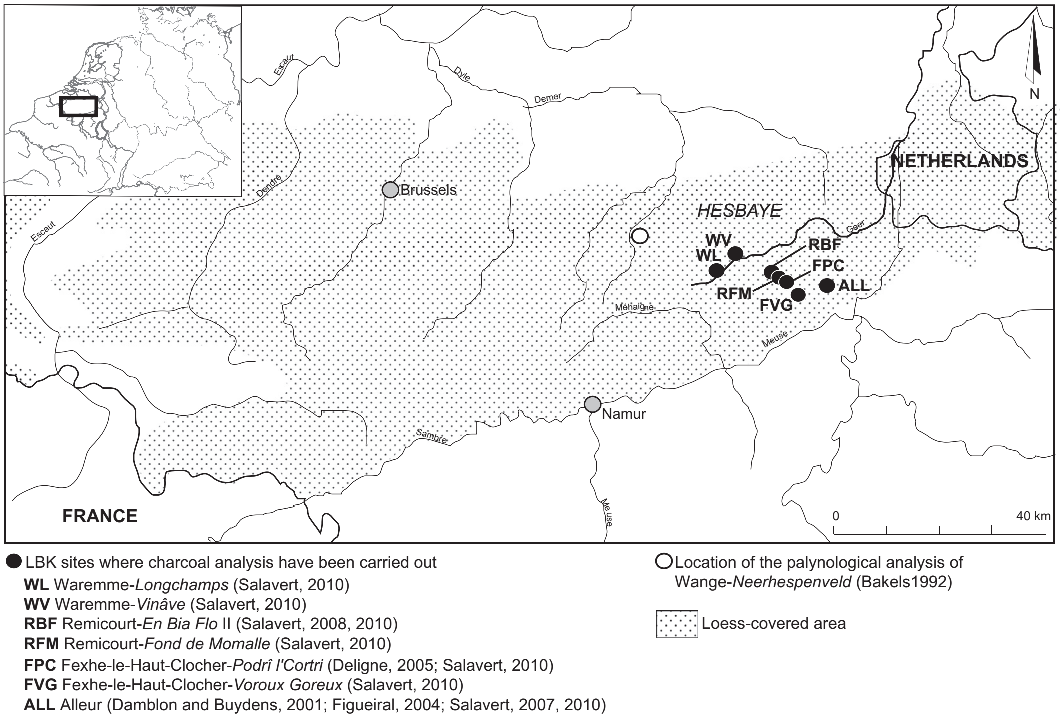

Fig. 2. Location of LBK sites where charcoal and pollen analyses have been carried out in Hesbaye at the east of the loessic belt of central Belgium.

3. Method

3.1. Sampling context and palaeoecological representativeness of the charcoal assemblages

The charcoal analyses were carried out in 116 features, most of which were pits. Two fireplaces and one posthole were also sampled at Alleur, as well as two sections of a surrounding ditch at *Longchamps*. Most of the material is coming from layers described as classical refuse dumps and consist of a mixture of waste from everyday life: ceramic sherds, lithics, charred ecofacts (charcoal, seeds, fruits) and burned earth fragments. Their thickness varies from 15 to 80 cm. In these contexts, we assume that charcoal fragments were coming from cleaning out of domestic and/or craft fireplaces. Observations of how lithics and ceramics are vertically distributed in the filling let us propose that detritus has certainly been deposited in the pits after a first phase of accumulation on the ground surface, a manner of refuse management that Last (1998) defined as an indirect discharge. These objects where rejected in the pits with other refuse such as charcoals after some time and one or several recycling phases (Bosquet et al., 2010). Thus, the detritic sublayers may represent several events of fuel collection and the charcoal assemblages may be assumed to represent the wood vegetation in the fuel supplying area (Chabal, 1994). In such a context, charcoal studies are useful for palaeoenvironmental reconstructions (Chabal, 1994, 1997; Bosquet et al., 2010).

A total of 14,651 fragments were identified. At Waremme–*Vinâve*, only two LBK pits were excavated and 316 fragments identified whereas at Remicourt-*En Bia Flo* II, 26 structures have been sampled and more than 3500 charcoal fragments observed. The heterogeneity in the number of charcoal and features studied is mainly due to the differences between spatial extent of excavations and preservation of archaeological structures.

Chabal (1997) recommends the study of at least 150 charcoal fragments – ideally 350 – by stratigraphic unit in Mediterranean regions. This number is based on studies in the Languedoc (south of France) where the taxonomic list is likely to be much higher because of a higher plant biodiversity than in central Belgium. Furthermore, this methodology was tested mainly on Iron Age and Roman sites. During these periods, charcoal fragments are generally much more numerous. The minimum number of charcoal fragments to study per stratigraphic unit can theoretically be revised downward in the north-western temperate regions. As far as possible, we try to identify a minimum of 100 fragments per sample. However, the richness in charcoal of each sample did not always allow to reach such level. Each time a new taxa is identified, we consider that examine up 50 charcoal fragments is sufficient to stabilize the "saturation curve" (Asouti and Austin, 2005: 7) and to have an overview of the past vegetation in temperate areas. The total number of samples studied ($n = 273$) in central Belgium allows us to judge the reproducibility of results at site and micro-region levels and thus the palaeoecological representativeness of the charcoal analysis.

3.2. Charcoal extraction and identification

In the great majority of sites, layers containing charcoal were systematically sampled during the fieldwork. In the laboratory, sediments were sieved in the water through a thin mesh (250 μm) to also allow analysis of macroremains (Salavert, 2011). Charcoal fragments were split according to the three plans of anatomical observation (transversal, longitudinal tangential, longitudinal radial). The identification of fragments was undertaken using a reflection microscope (×50–×500). Measuring firewood diameters using circle or trigonometric tools could not be achieved due to the small size of charcoal fragments, in particular the transversal section, and the conservation of only one or two rings.

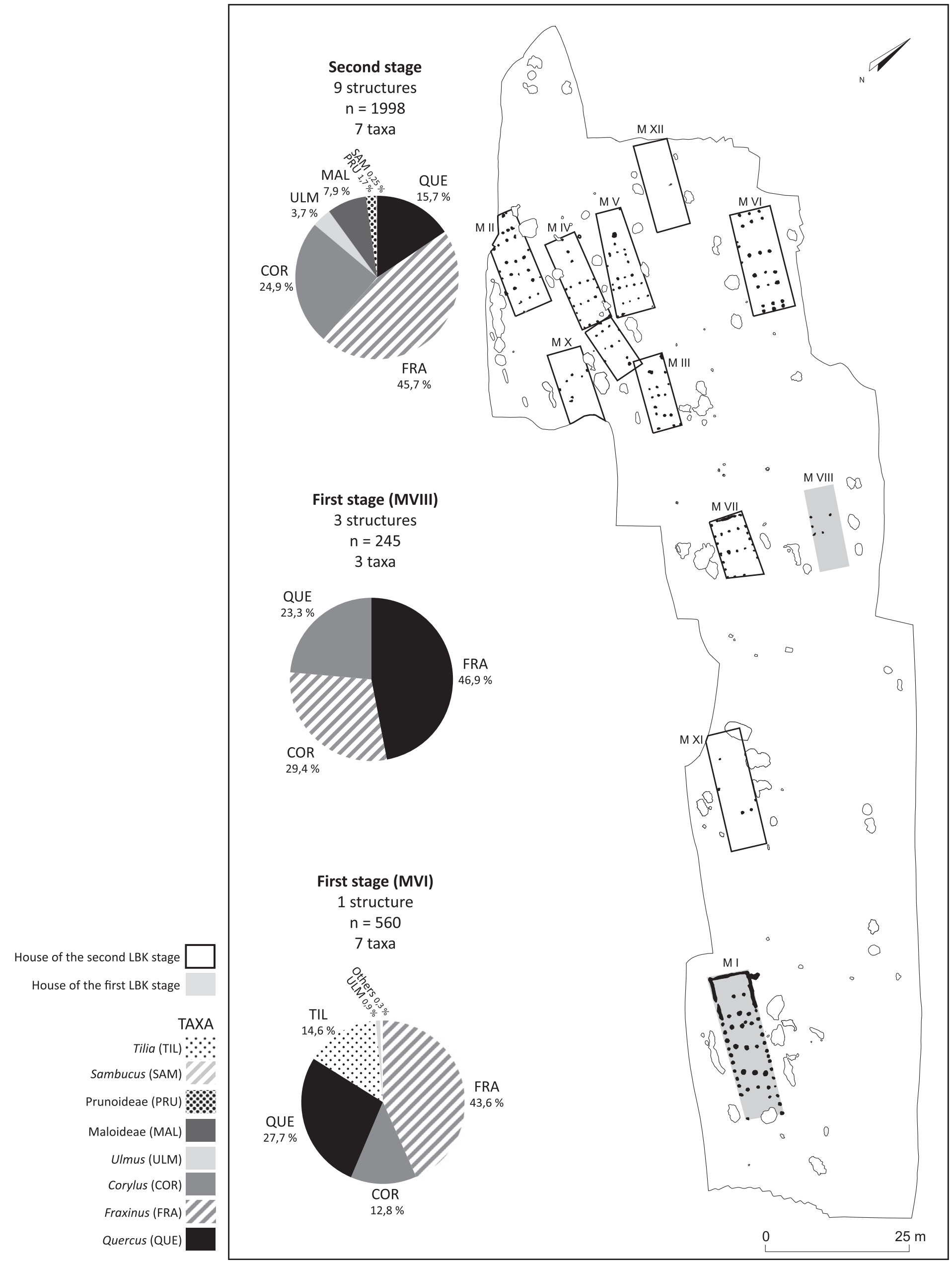

Fig. 3. Charcoal assemblages, number of structures analysed and number of charcoal identified (n) of the first (houses VI and VIII) and the second stage of settlement at Fexhe-le-Haut-Clocher—*Podrî l'Cortri* (FPC).

The work presented in this paper is founded on charcoal analyses led mainly by Salavert (2008, 2010). Deligne (2005) realized the analysis of *Podrî Cortri*. Damblon and Buydens (2001), as well as Figueiral (2004), studied some structures of Alleur.

4. Results

4.1. Charcoal analysis

A total of 1974 fragments of charcoal were identified in 12 features dated to the first stage. The pits are related to houses I and VIII of *Podrî l'Cortri* (Fig. 2), house V of *Bia Flo* (Fig. 4), house I of *Longchamps* (Fig. 5), and structures of *Vinâve* (Table 1). The main taxa are *Quercus*, *Fraxinus* and *Corylus*. They are present in every site as well as almost every structure and make up 73% of the charcoal assemblage (Fig. 6). Fragments of *Ulmus* and *Tilia* are generally in low quantities, except at *Vinâve* where 8.5% of *Ulmus* is identified and in the house I of *Podrî l'Cortri* where *Tilia* comprised 14.8% (Fig. 3). These percentages are probably due to an over-representation of these taxa at the structure scale. Those two taxa are identified respectively in four and three sites and in less than half of the 12 structures. Maloideae and *Sambucus* are both represented by a single fragment at *Podrî l'Cortri*.

A total of 12,677 fragments were identified in 86 structures of the second stage and distributed across six sites: *Podrî l'Cortri*, *Bia Flo* and *Longchamps*, *Voroux Goreux* and most of the structures of *Alleur* and *Momalle* (Table 1). *Quercus* (35%) and *Fraxinus* (24%) are the two main taxa accompanied by Maloideae and *Corylus* (about 14% each). These four taxa are present on each site and in more than two thirds of the 86 structures of the second stage. Prunoideae,

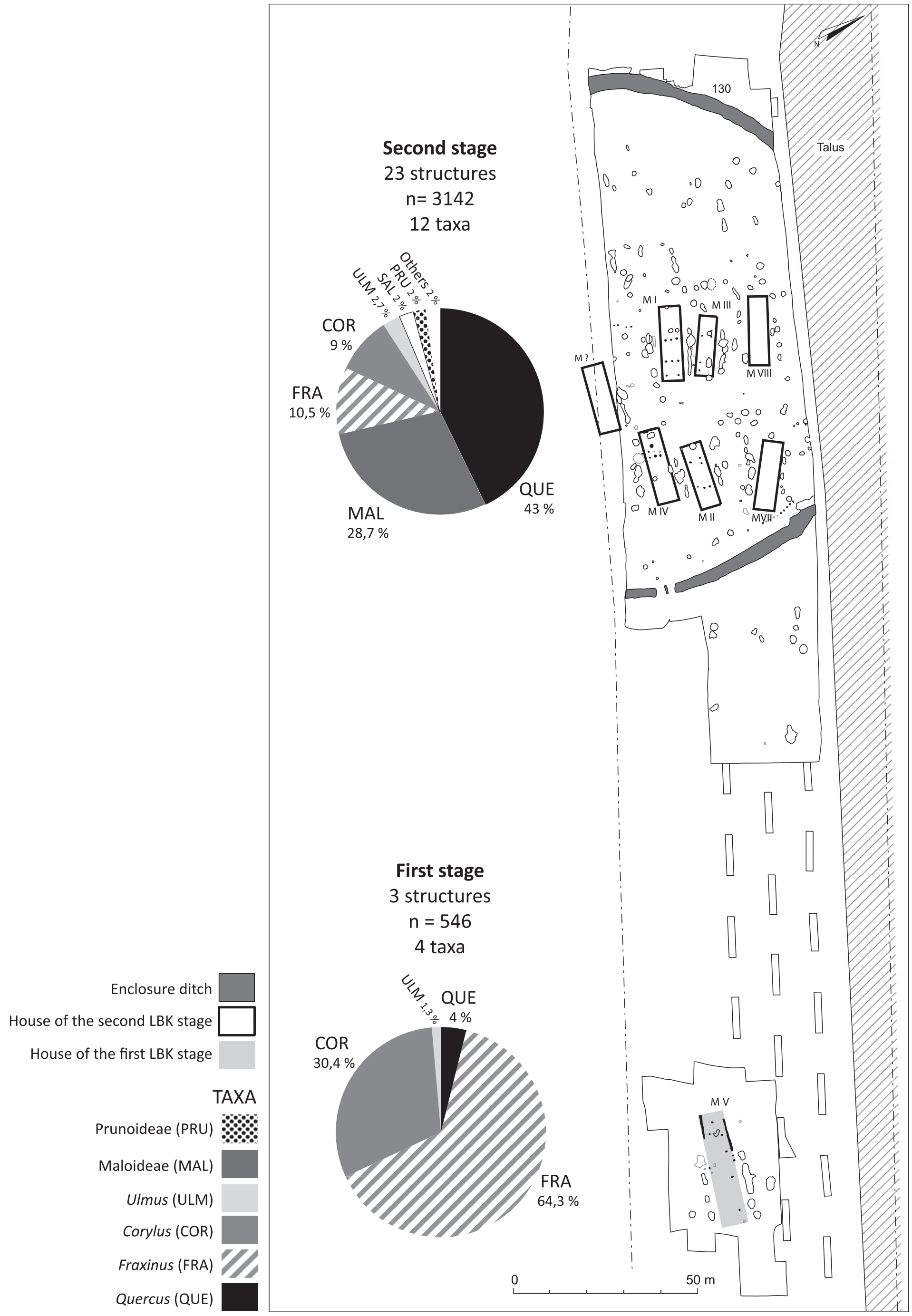

Fig. 4. Charcoal assemblages, number of structures analysed and number of charcoal identified (*n*) of the first (house V) and the second stage of settlement at Remicourt–*En Bia Flo* II (RBF).

Ulmus and *Sambucus*, make up less than 10% of the assemblage, are also regularly identified. Prunoideae and *Ulmus* are present on each site and in more than one third of the structures, whereas *Sambucus* is encountered on four sites and in 21 structures. *Salix*/*Populus*, *Acer*, *Tilia*, *Betula*, *Ligustrum* and *Cornus* are present on one or two sites.

The charcoal assemblage of the first stage has a relatively low diversity. Most often, only four or five taxa are identified, mainly *Quercus*, *Fraxinus* and *Corylus*, while *Tilia* and *Ulmus* are in the minority. A total of 12 structures and 30 samples were analysed in archaeological contexts similar to those of the second stage. Thus, the dataset related to the first stage allows to judge the reproducibility of results and to say that the low number of taxa and the monotony of the results are not related to methodological reasons. Charcoal assemblages of the second stage present a higher diversity (up to 14 taxa). The most important species are still *Quercus*, *Fraxinus* and *Corylus*, together with Maloideae, Prunoideae and *Sambucus*. Furthermore, *Maloideae* are not represented in the first stage if we exclude one charcoal fragment identified at *Podrî l'Cortri*. In contrast, Maloideae are recorded in the six sites of the second stage and in 65% of the structures. In the same way, one fragment of *Sambucus* is identified at *Podrî l'Cortri*, whereas this taxon is recorded in 24% of the second stage structures.

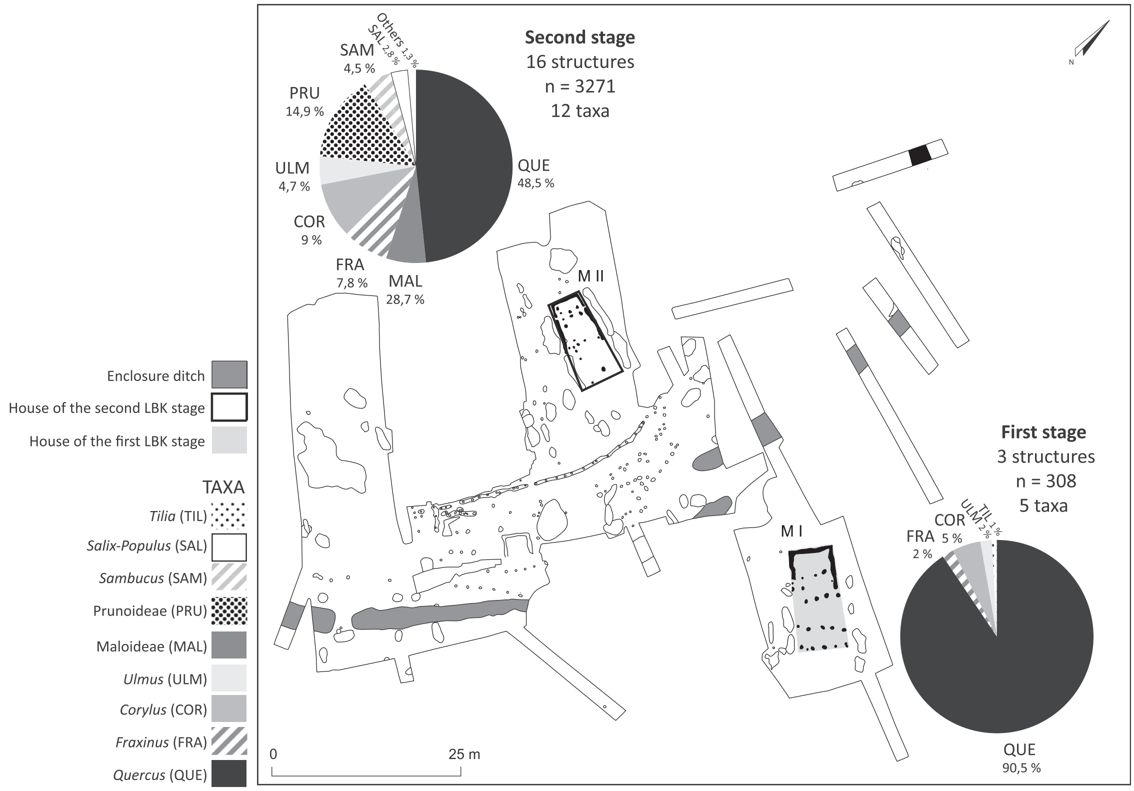

Fig. 5. Charcoal assemblages, number of structures analysed and number of charcoal identified (*n*) of the first (house I) and the second stage of settlement at Waremme–*Longchamps* (WL).

5. Discussion

5.1. Natural forest at the arrival of LBK groups in Hesbaye

During the first stage of settlement, only a few forest species, dominated by *Quercus*, *Fraxinus* and *Corylus*, were exploited (Fig. 6). Are the monotony and low taxonomic diversity of the charcoal assemblage of the first stage related to environmental and/or technical/economic constraints? In other words, does charcoal assemblage reflect the composition of the natural forest in the vicinity of LBK sites or the selection of firewood at the arrival of LBK groups in Hesbaye?

The site of Wange-*Neerhespenveld* is the nearest off-site pollen core that give results for the Atlantic period in Hesbaye (Bakels, 1992). The site is located on the right bank of the Petite Gette few miles north of the Geer (Fig. 2). The pollen diagram also indicates a quite low species diversity at the arrival of LBK groups with mainly *Corylus*, *Quercus*, *Tilia* and *Ulmus* (Bakels, 1992). However, pollen grains, as for the archaeological charcoal, do not reflect the full diversity of the forest, but the majority of species present in the vicinity of sites. For example, Rosaceae and other shrubs like *Sambucus* are rarely encountered in pollen records, even when their presence is attested by charcoal remains. The absence of Rosaceae pollens in the palynological core does not actually indicate the absence of these plants in the LBK forest, notably the natural forest at the arrival of LBK groups around 5200 b.c. in Hesbaye. During the first stage of settlement, it is quite likely that shrubs and medium size heliophilous trees, such as Rosaceae, may have developed in local patches, under the impact of natural factors like fire or tree death (Kreuz, 2008) but that such patches were not exploited for firewood. In Hesbaye, charcoal assemblage indicates the exploitation of a forest with a canopy closed enough to not allow the development of shrubs and medium size heliophilous trees in the undergrowth. Today, this configuration is well illustrated by the case of the Białowieska forest, in Poland, where shrubs are confined to gaps in an uneven-aged high forest of oak–lime–hornbeam stands (Peterken, 1996: 75). However, the abundance of *Corylus* could indicate the existence and exploitation of gaps in the forest which could favoured taxonomic diversity. Today, this taxa is associated to forest edges. However, even if light is essential for its regeneration, *Corylus* is a pioneer half-shade specie (Oberdorfer, 1979; Noirfalise, 1984; Rameau et al., 1989) and thus, could live in the undergrowth of an oak forest. The absence of shrubs and Rosaceae could also be explained by economic or technological choices which influence firewood collection (Dufraisse, 2011). Despite the presence of few Rosaceae, the first LBK people could have preferred the tall trees like *Quercus* and *Fraxinus*, more adapted to their technical needs, for building for example. *Corylus* could also have been used for building thanks to its little diameter useful, notably, for wattle-and-daub technique (Billard et al., 1997). If we consider this hypothesis, charcoal may correspond to timber wastes reused as firewood. However, we need more archaeological evidence to demonstrate such selection like charcoal fragments large and numerous enough to allow the analysis of wood diameter.

Furthermore, even if the dataset of the first stage has to be supplemented, *Tilia* seems to be more frequent during the first stage (42% of the structures) than during the second stage (9% of the structures) and may support that first LBK groups settled in a forest not much modified around 5200 b.c. Indeed, based on palynological results in central Belgium and more widely in central and western Europe, *Tilia* was an important component of the early Atlantic forest as well as *Ulmus*, *Corylus*, and to a lesser extent, *Quercus* and *Fraxinus* (Munaut, 1967; Damblon, 1978; Bakels, 1992; Heim, 1996; Kalis et al., 2003). However, charcoals of *Tilia* are rarely identified in

LBK assemblages, perhaps because of its poor combustion properties or that the tree was preferred for others activities than domestic firewood (Kreuz, 1992; Dambon and Hauzeur, 2005–2006). In Hesbaye, the presence of *Tilia* fragment could indicate its high availability in the vicinity of LBK sites. However, its percentage remains low in the charcoal assemblages comparing to its probable importance in LBK landscape indicating by pollen recordings (Bakels, 1992; Kreuz, 1992, 2008; Dambon and Hauzeur, 2005–2006).

In central Europe, few sites provide valuable archaeological contexts informing on the natural forest composition at the arrival of LBK groups. To our knowledge, this configuration is attested at Remerschen–*Schengerwis* in the Grand Duchy of Luxembourg (Damblon and Hauzeur, 2005–2006), and in Hessen where several sites have been analysed (Kreuz, 1990, 1992, 2008). At Remerschen, the earliest LBK structures are attributed to the middle LBK. The charcoal assemblage is very similar to what is observed in Hesbaye, with low species diversity (mainly *Fraxinus*, *Quercus* and *Corylus*) during middle LBK and a higher species diversity of species in recent and final LBK assemblages. On the other hand, in Hessen, the earliest charcoal assemblages attributed to the first phase of LBK extension (LBK I) provide high species diversity and Rosaceae (Kreuz, 1990, 1992, 2008, 2012). Many explanations can be given to explain the differences in the composition of pioneer charcoal assemblages west (central Belgium, Luxembourg) and east (Hessen) of the Rhine. For example, sampled layers may not be comparable in terms of activities involved or duration of occupation. The status of the earliest domestic units, strategies of firewood collecting and choice of settlement areas could be different between both sides of the river. Furthermore, the opening of forest canopy at the arrival of the first LBK groups could have been heterogeneous within the LBK territory because of the degree of Mesolithic groups impact on the forest. Indeed, in Hessen, the forest seems to have had already been subjected to human impact since the early Mesolithic as it has been demonstrated by Bos and Urz (2003). To the contrary, in central Belgium, an interregional comparison of microlith datasets has shown that the first agro-pastoral populations seem to have settled in areas only marginally exploited by late Mesolithic hunter–gatherers (Vanmonfort, 2008). Thus, the influence of Mesolithic groups seems to have been scarce in the loessic Belgium even if the Mesolithic occupation density is difficult to evaluate because most of sites have been destroyed by extensive agriculture which is particularly developed in the region since the 17th century. The forest canopy could have been more open in Hessen and explain the fact that heliophilous species are already identified in the earliest charcoal assemblages (LBK I) in this region. However, this hypothesis needs further investigation.

5.2. Vegetation during the second stage of settlement in central Belgium and importance of Maloideae

During the second stage of settlement, charcoal assemblage indicates that the diversity of taxa increases and that forest species were still collected together with the post-pioneer light-demanding taxa (Rosaceae). The latter indicate the exploitation of areas subject to forest recovery as forest edges. Today, Rosaceae species are among the main component of forest edges in temperate forest. The creation of hedgerows is hard to demonstrate solely on the basis of the taxa identified. Hedges involve fixed boundaries between villages and fields as well as particular management techniques, such as pruning. To the contrary, forest edges can be sharp or gradual boundaries and can be mobile in time and space between forest, field and/or pasture. *Sambucus*, *Ligustrum*, *Cornus*, *Corylus*, *Ulmus* and *Acer* could also be associated with edges as well as *Salix/Populus*. Indeed, due to the absence of *Alnus*, the riparian forest, which was subject to periodic flooding, was probably not much exploited by LBK groups for firewood while the pollen diagram of Wange–*Neerhespenveld* shows the presence of *Alnus* at a local scale (Bakels, 1992).

Species of the subfamily Maloideae are present, and sometimes even dominant, during the second stage. They were identified in 65% of structures attributed to this stage while they are represented by only one fragment in an earliest structure of *Podrî l'Cortri*. Furthermore, in Hesbaye, their percentage varies depending on the site. The cutting of tall trees during the first stage of settlement may have favoured their development. At *Bia Flo* and *Voroux Goreux*, the percentage is about 29% whereas it varies from 7 to 9% at the four others sites belonging to the second stage of settlement. Actually, to interpret such percentages, we are limited by the fact that the different genera (*Crataegus*, *Sorbus*, *Malus*, *Pyrus*) that compose the Maloideae subfamily have a very similar wood anatomy. It may change the interpretation of the importance of Maloideae in LBK fuel economy and the techno-economic role of edges in the LBK landscape. On one hand the presence of crab apple pips and fruit fragments in macro-remain assemblages of Neolithic central Belgium (Van der Sloot et al., 2003; Salavert, 2011) and the importance of Maloideae charcoal fragment could indicate the management of wild apple tree for fruit production; but no solid archeobotanical evidences supports this assumption at the

Table 1

Results of the charcoal analysis of the pioneer and post-pioneer occupation of Hesbaye. *n* charc. = number of charcoal identified on the site; % charc. = percentage of charcoal identified on the site; ub. = ubiquity, number of structures in which the taxon is identified. For example, in the first stage of settlement of Remicourt-*En Bia Flo* II (RBF), 22 fragments of Quercus are identified. It corresponds to 4% of the 546 charcoals identified. Quercus is recognized in 2 of the 3 structures studied on the site.

	Number of fragments	Number of structures	*Quercus* sp.			*Fraxinus excelsior*			*Corylus avellana*			*Ulmus* sp.			*Tilia* sp.			*Maloideae*			*Prunoideae*	
			***n* charc.**	% charc.	**ub.**	***n* charc.**	% charc.	**ub.**	***n* charc.**	% charc.	**ub.**	***n* charc.**	% charc.	**ub.**	***n* charc.**	% charc.	**ub.**	***n* charc.**	% charc.	**ub.**	***n* charc.**	% charc.
First stage of settlement																						
RBF (MV)	546	3	22	4	2	351	64.3	3	166	30.4	3	7	1.3	2	–	–	–	–	–	–	–	–
WL (MI)	308	3	279	90.6	3	6	2	2	15	4.9	1	6	2	1	2	0.7	2	–	–	–	–	–
FPC (MI et VIII)	804	4	212	26.4	3	359	44.6	4	144	17.9	4	5	0.6	1	82	10.2	1	**1**	0.1	**1**	–	–
WV	316	2	164	51.9	2	82	25.9	2	40	12.7	2	27	8.5	2	3	0.9	2	–	–	–	–	–
Total	1.974	12	677	34.3	10	798	40.4	11	365	18.5	10	45	2.3	5	87	4.4	5	1	0.05	1	–	–
Second stage of settlement																						
RBF (MI-IV)	3142	23	1349	42.9	22	330	10.5	14	279	8.9	14	84	2.7	8	2	0.2	4	901	28.7	22	67	2.1
WL (MII+surrounding ditch)	3271	16	1587	48.5	16	254	7.8	9	299	9.1	13	154	4.7	9	20	0.6	3	219	6.7	8	474	14.9
FPC (MII-VII)	1998	9	313	15.7	9	914	45.7	8	498	24.9	9	75	3.7	4	–	–	–	158	7.9	8	35	5.3
RFM	1425	22	199	14	11	927	65	18	132	9.3	8	10	0.7	2	–	–	–	129	9	7	22	1.5
ALL	2030	12	527	26	10	610	30	7	569	28	7	91	4.5	5	1	0.05	1	180	8.9	5	4	0.2
FVG	811	4	450	55.5	4	32	4	2	6	0.7	3	32	4	2	–	–	–	236	29.1	4	55	6.8
Total	12.677	86	4425	34.9	72	3067	24.2	58	1783	14.1	54	446	3.5	30	23	0.2	8	1823	14.4	54	657	5.2

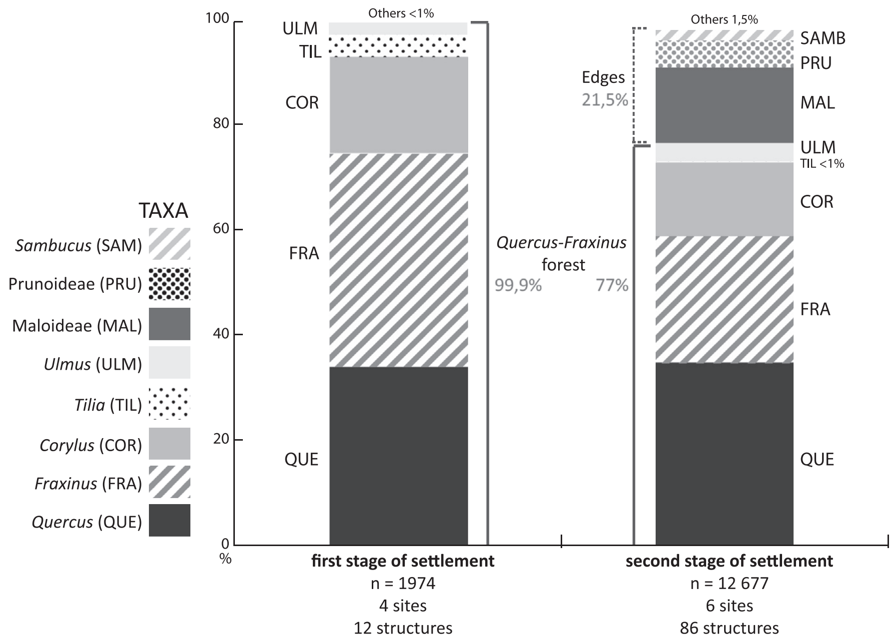

Fig. 6. Charcoal assemblages of the first and second stages of LBK settlement in Hesbaye, as well as forest communities exploited. n = number of charcoal identified.

moment. On the other hand, the high percentage of Maloideae on two Hesbaye sites can indicate a higher territorial influence because of demographic/spatial importance of the villages. It could imply a more significant impact of agro-pastoral activities on the vegetation around the village offering good conditions to the growing of Maloideae.

The importance of Maloideae species in LBK structures is verified on many LBK sites in central and north-western Europe, supporting the link between the presence of Maloideae and the rising impact of human activities on Neolithic sites (Kreuz, 1990, 1992, 2008; Castelletti and Stäuble, 1997; Damblon et al., 2001-2002; Damblon and Hauzeur, 2005–2006; Kirleis and Willerding, 2008).

5.3. Vegetation dynamic during LBK period in north-western Europe

The charcoal assemblages of the first and second stages of settlement in Hesbaye give an overview of two landscapes that have been exploited in a time interval of two centuries (5200–5000 b.c.). During the first stage of settlement, the main components of *Quercus*–*Fraxinus* forest were exploited, indicating that LBK groups could have settled within a rather closed canopy. Then, during the second stage of occupation, the forest edges were exploited probably in the vicinity of the LBK sites. However, charcoal assemblages do not offer a continuous dynamic across the whole LBK period. Indeed, many questions remain, notably concerning the link between agro-pastoral systems and the forest-opening process as well as the speed of edge developments.

According to present day ecology of modified natural and semi-natural forests, "forests bordering agricultural areas may provide additional habitats and thus harbour more species" (Global Forest Resources Assessments, 2005: 40). Margins and forest limits mark the interface between forest, cultivated areas and/or pasture lands. They are probably the first affected by fragmentation, transformation and exploitation of the landscape by humans. The start of an opening's dynamic in a natural forest progressively favours the availability of light, nutrients and water for undergrowth plants, and explains the increase in species diversity (Ellenberg, 1988). The land clearings created by first LBK people

Prunoideae	*Sambucus* sp.			Cf. *Frangula* sp.			Cf. *Ligustrum* sp.			*Acer* sp.			*Betula* sp.			Cf. *Cornus* sp.			*Salix/Populus*		
ub.	***n* charc.**	% charc.	**ub.**	***n* charc.**	% charc.	**ub.**	***n* charc.**	% charc.	**ub.**	***n* charc.**	% charc.	**ub.**	***n* charc.**	% charc.	**ub.**	***n* charc.**	% charc.	**ub.**	***n* charc.**	% charc.	**ub.**
First stage of settlement																					
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	1	0.1	**1**	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	1	0.05	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Second stage of settlement																					
13	43	1.4	7	**12**	0.4	**3**	**1**	0.03	**1**	**1**	0.03	**1**	–	–	–	–	–	–	**69**	2.2	**6**
8	148	4.5	9	–	–	–	**19**	0.6	**4**	–	–	–	**4**	0.1	**1**	**1**	0.03	**1**	**92**	2.8	**7**
5	5	0.25	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	6	0.4	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1	47	2.3	3	–	–	–	–	–	–	–	–	–	**1**	0.05	**1**	**1**	0.05	**1**	–	–	–
3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
32	249	2	21	**12**	**0.1**	**3**	**20**	**0.2**	**5**	**1**	**0.01**	**1**	**5**	**0.04**	**2**	**2**	**0.02**	**2**	**161**	**2.1**	**13**

could have promoted the development of light-demanding post-pioneer species such as the Maloideae and Prunoideae. As a hypothesis, we suggest that the collecting of firewood and pasture areas could have been spatially separated during LBK period. Indeed, animal grazing is harmfull to Rosaceae and shrubs regeneration which could have developed near habitats and fields. The floodplain or rivers shores could have been used as pasture (Kreuz, 2008) whereas no indication of their exploitation for firewood collecting is highlighted in charcoal assemblages of Hesbaye. The role of animal foddering was also probably important in the intensity, expansion and maintaining of open areas during the second stage of occupation even if the husbandry system (herd size, number of cattle kept per house unit, fodder quantity, etc) is not yet fully understood for the LBK period (Ebersbach and Schade, 2004).

Finally, the sudden appearance of Maloideae, Prunoideae and shrub species questions on the rapidity of vegetal dynamic and edge development around LBK sites of the Geer valley. In Hesbaye, the whole LBK period lasted around two centuries (Jadin, 2003). Furthermore, the earliest houses are very close (from a few to around 130 m) to the area occupied by the second stage structures at *Podrî l'Cortri, Bia Flo* and *Longchamps*. This might indicate that the development of heliophilous species between the first and the second settlement may have been a relatively fast event. However, the indirect discharges of detritic layers after an accumulation on the ground surface of an indeterminate duration (Bosquet et al., 2010) does not offer useful data for understanding the processes of woodland opening through the second stage of settlement.

6. Conclusion

The development of forest edge plant communities seems to be the first consequence of the arrival of sedentary groups of agriculture in Hesbaye and also in the Grand Duchy of Luxembourg. LBK groups appear to have fragmented the natural woodland favouring the habitats for the development of heliophilous and shrub species and may have intensively exploited areas of forest recovery for collecting fuel. The process of the increase of Maloideae percentage remains unclear and has to be further investigated. Moreover, this study has shown that charcoal material could be a good support to ceramic and lithic studies to differentiate the first and second stage of settlement in Hesbaye. Additional charcoal analyses of LBK sites in Hesbaye and adjacent areas (Limburg, Paris Basin, Moselle) as well as investigations on late Mesolithic sites should give a better understanding of the natural forest composition and its dynamic under the influence of agro-pastoral communities during the second half of the 6th millenium b.c.

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